

CLAIMS

What is claimed is:

1. A haptic interface device to provide haptic interaction to a user manipulating a tool, the haptic interface device comprising:
 - an attachment point;
 - a first cable having a first and a second end, the first end coupled to the attachment point;
 - a first tool translation effector device having coupled thereto the second end of the first cable, the first tool translation effector device including controlling means for controlling the first cable such that, as the attachment point moves, the first cable is retracted or paid out accordingly by the first tool translation effector device;
 - metering means for metering the first cable as it is retracted and paid out;
 - and
 - establishing means for establishing, during an initialization procedure, a distance between the first tool translation effector device and the attachment point.
2. The haptic interface device of claim 1 wherein:
 - the controlling means includes a spool and a motor coupled to rotatably drive the spool, the motor and spool selectively operable to wind and unwind the second end of the first cable; and
 - the metering means includes:
 - counting means for counting fractions of rotations of the spool; and
 - compensating means for compensating for a change in ratio between changes in distance from the first tool translation effector device to the attachment point and angular rotation of the spool.

3. The haptic interface device of claim 1 wherein the establishing means includes a controller configured to direct the first tool translation effector device to retract, during an initialization procedure, the first cable until the attachment point is in contact with the first cable control unit.

4. The haptic interface device of claim 1 wherein the establishing means includes a memory configured to receive, prior to a shutdown of the device, a known distance and to provide the known distance during a startup procedure.

5. The haptic interface device of claim 1 wherein the establishing means includes at least one sensor configured to determining a position of the attachment point relative to the first tool translation effector device.

6. The haptic interface device of claim 5 wherein the establishing means includes means for reestablishing the distance from time to time during operation.

7. The haptic interface device of claim 1, further comprising:
second, third, and fourth cables coupled at respective first ends to the attachment point;

second, third, and fourth tool translation effector devices positioned, relative to each other and to the first tool translation effector device, such that each of the first, second, third, and fourth tool translation effector devices occupies a vertex of a tetrahedron; and

a sensor array associated with the attachment point and configured to provide signals corresponding to an orientation of the attachment point.

8. The haptic interface device of claim 7 wherein the sensor array is configured to provide signals corresponding to roll, pitch, and yaw of the attachment point.

9. The haptic interface device of claim 1 wherein the attachment point is configured to receive the tool, the haptic interface device further comprising:

second, third, and fourth cables coupled at respective first ends to the attachment point;

second, third, and fourth tool translation effector devices positioned, relative to each other and to the first tool translation effector device, such that each of the first, second, third, and fourth tool translation effector devices occupies a vertex of a tetrahedron; and

a sensor array associated with the attachment point and configured to provide signals corresponding to an orientation of the tool.

10. The haptic interface device of claim 1, further comprising:

second and third cables coupled at respective first ends to the attachment point; and

second and third tool translation effector devices positioned in a triangular configuration relative to each other and to the first tool translation effector device.

11. The haptic interface device of claim 1 wherein the controlling means includes tensioning means for selectively varying tension on the first cable.

12. A haptic device for operation by a user, comprising :

a user interface tool configured to be manipulated by the user and moved within a volume of space;

a first, a second, a third, and a fourth tool translation effector device, each coupled to a support structure in positions such the first, second, third, and fourth tool translation effector devices define between them a tetrahedron within the volume of space, each of the tool translation effector devices including a respective spool and a respective encoder configured to provide a signal corresponding to rotation of the respective spool;

first, second, third, and fourth cables each having a respective first and a respective second end, the first end of each of the first, second, third, and fourth cables coupled to the user interface tool and the second end of each of the first, second, third, and fourth cables wound and unwound on the spool of a respective one of the tool translation effector devices; and

a first sensor configured to detect rotation of the user interface tool around an axis.

13. The haptic device of claim 12 wherein the first sensor is configured to detect rotation in each of three mutually perpendicular axes.

14. The haptic device of claim 12, further comprising a processor system coupled to receive information from the sensor array and coupled to receive the signals from the respective encoders, the processor system configured to determine movement and orientation of the tool therefrom.

15. The haptic device of claim 14 wherein the processor system is configured to compensate for changes in effective diameter of the spools of the first, second, third, and fourth tool translation effector devices due to changing thickness of cable on each of the spools as the respective cable is wound and unwound from the respective spool.

16. The haptic device of claim 14 wherein each of the first, second, third, and fourth tool translation effector devices further comprises:

a motor coupled to the respective spool, each of the motors operable to selectively apply tension to the respective cable.

17. The haptic device of claim 16 wherein the processor system is configured to establish an initial position of the tool by retracting, in turn, each of the first, the second, the third, and the fourth cables to a known length position.

18. The haptic device of claim 14, further comprising:

a port coupled to the support structure; and

wherein the user interface tool comprises a tool shaft having a first and a second end, the first end of each of the first, second, third, and fourth cables coupled to the first end of the tool shaft, the tool shaft passing through the port such that the tool shaft pivots at the port and manipulation of the second end of the tool shaft is reflected in movement of the first end of the tool shaft.

19. The haptic device of claim 18 wherein the first sensor is located at the port and coupled to the tool shaft.

20. The haptic device of claim 18, further comprising a second sensor coupled to the second end of the tool shaft and configured to detect gripping force exerted by the user.

21. The haptic device of claim 18 wherein the second end of the tool shaft is configured to provide for the user a simulation of a selected tool.

22. The haptic device of claim 21 wherein the selected tool is formed as one of a stylus, a pen, a pliers, a wrench, a forceps, a scalpel, an endoscope, or an arthroscope.

23. The haptic device of claim 18, further comprising:
a feedback device coupled to the tool shaft and configured to selectively apply rotational force to the tool shaft.

24. The haptic device of claim 23 wherein the feedback device is located at the port.

25. The haptic device of claim 18, further comprising:
a feedback device coupled to the second end of the tool shaft and configured to selectively resist gripping force exerted by the user.

26. The haptic device of claim 14 wherein the processor system is configured to maintain a virtual environment within which the user interface tool is operated, and to provide feedback from the virtual environment to the user interface tool.

27. The haptic device of claim 14, further comprising:
a remote tool, and wherein the processor system is configured to control operation of the remote tool in accordance with the movement and orientation of the user interface tool.

28. The haptic device of claim 27 wherein the processor system is configured to provide feedback from the remote tool to the user interface tool.

29. A method, comprising:

applying tension to each of a plurality of cables each having respective first and second ends, each of the plurality of cables coupled at its respective first end to a tool, and at its respective second end to a respective anchor point;

measuring a change of cable length between the tool and each respective anchor point; and

establishing an initial length of cable between the tool and each of the anchor points.

30. The method of claim 29 wherein establishing an initial length of cable comprises moving the tool in turn to each of the anchor points such that the length of cable between the tool and the respective anchor point is effectively zero.

31. The method of claim 29 wherein establishing an initial length of cable is performed during a startup procedure.

32. The method of claim 29 wherein establishing an initial length of cable comprises:

storing a value indicative of a known length of each cable in a memory during a shutdown procedure; and

recovering the value indicative of the known length of each cable from the memory during a startup procedure.

33. The method of claim 29 wherein establishing an initial length of cable comprises:

tracking a position of the tool; and

correlating the position of the tool with known positions of the anchor points.

34. A method, comprising:

applying tension to a cable having a first end and a second ends, the first end of the cable coupled to a tool and the second end of the cable coupled to an anchor point;

as the tool is moved closer to the anchor point, winding the cable onto a spool;

as the tool is moved away from the anchor point unwinding the cable from the spool;

tracking a distance of the tool from the anchor point by counting fractional rotations of the spool as the cable is wound and unwound therefrom; and

compensating for changes in effective diameter of the spool as the effective diameter changes in response to the cable being wound and unwound therefrom.

35. The method of claim 34 wherein the cable is one of a plurality of cables having respective first and second ends, the first ends coupled to the tool and the respective second ends coupled to respective anchor points, and further comprising:

winding each of the plurality of cables onto a respective spool as the tool is moved closer to the respective anchor point;

unwinding each of the plurality of cables from the respective spool as the tool is moved away from the respective anchor point;

tracking a distance of the tool from each of the respective anchor points by counting fractional rotations of each of the respective spools; and

compensating for changes in effective diameter of each of the respective spools as the effective diameter changes in response to the respective cable being wound and unwound therefrom.

36. The method of claim 34 wherein:

the number of cables in the plurality of cables is equal to three; and

the respective anchor points are positioned in a triangle that defines a plane in which the tool has freedom to move.

37. The method of claim 34 wherein:
the number of cables in the plurality of cables is equal to four; and
the respective anchor points are positioned at respective vertices of a tetrahedron positioned within a volume of space in which the tool has freedom to move.

38. A method, comprising:
applying tension to each of four cables, each cable having a first end coupled to a tool and having a second end coupled to a respective vertex of a tetrahedron such that, as the tool is moved closer to any of the vertices the respective cables are drawn in at the respective vertices, and as the tool is moved away from any of the vertices the respective cables are fed out from the respective vertices;
measuring a length of cable drawn in or fed out at each of the vertices;
and
measuring rotation of the tool about an axis by receiving a signal from a sensor operatively coupled to the tool.

39. The method of claim 38 wherein the measuring rotation step comprises measuring rotation of the tool about three mutually perpendicular axes.